Comparative Analysis of Grindability of Iron-ore and Granite

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Abstract

Grindability of granite and Iron-ore was investigated in this work. Samples were collected from Julius Berger Quarry and National Iron-Ore Mining Company (NIOMCO), Itakpe. Particle size distribution of the samples by means of sieve shaker and grindability of samples were also determined. The results obtained show that weight retained varies from 36.71 g to 183.1 g for granite while that of iron-ore vary from 9.65 g to 87.78 g. In addition, it was observed that granite and iron-ore have grindability values of 0.061 g/rev and 0.926 g/rev respectively. This confirmed that granite requires more energy to be grinded.

Key words

Grindability; Granite; Iron ore; Particle Size; Sample

Introduction

In processing of ores, comminution, which involves crushing and grinding process has to be in place. The run of mine ore is reduced by crushing the ore such that grinding can be carried out until the mineral and gangue are substantially produced as separate particles. The treatment may be simple size preparation involving crushing, grinding, and screening or elaborate beneficiation involving physical cleaning of iron ore/granite rock or chemical processing. Crushing is an essential step in mineral processing. Also, in exposing mineral samples for effective separations, it has been found that particle size analysis must be in place. Size analysis of various mills' product constitutes a fundamental part of laboratory testing procedure. It is of great importance in determining the quality of grinding and in establishing the degree of liberation of the values from the gangue at various particle sizes. Bernhardt (1994) was of the view that one of the main functions of particle size analysis is to obtain quantitative data about the size and size distribution of particles in the material. Particle size analysis of the product could also be used to determine the optimum size of the feed to be processed for maximum efficiency as well as to determine the size range at which loss occurs in the plant so that they could be reduced.

This method (particle size analysis) must be accurate and reliable, since important changes in plant operation may be made on the result. Wills (2006) confirmed that particle size analysis using sieves is one of the oldest and most widely employed methods today. As a result of comminuting iron ore and granite rock, it is important to determine the hardness and the grindability characteristics of both materials so that suitable crushing and grinding equipment of suitable power rating can be selected for the comminution process. The choice of appropriate comminution equipment is very important because it is an energy intensive operation. In fact, it has been estimated that fifty percent (50%) of the energy used in processing of materials are consumed at this stage (Wills, 2006). The most widely used parameter for measuring the hardness and grindability of any ore (rock material) is its work index. The work index of an ore is its comminution parameter, expressed as the resistance of the ore to crushing and grinding and is numerically equal to the kilowatt hour per short tonne (KWHT) required to reduce the ore material from a theoretically infinite feed size to eighty percent (80%) passing one hundred micron (100 μm) (Wills, 2006).

If the mill speed is not lower than its centrifugal speed, the whole charge will rotate along with the mill body and no grinding will occur. This speed limit fixes the maximum electrical power the mill can draw.

Smith and Lee in 1968 used batch–type grindability tests which conformed to the result obtained when work indices from the standard Bond test was used. The batch–type test compares favourably with the advantage of less time consuming. Berry and Bruce (1966) developed a comparative method to determine the grindability of an ore. The method requires the use of a reference ore of known grindability, reasonable value of the work indices obtained as long as the

reference and test ores are ground to about the same product size distribution.

Lawrison (1974) obtained work indices from grindability test on different size of several types of equipment, using identical feed materials. The value of work indices obtained is indicative of the efficiencies of the machines. The most widely used parameter to measure ore grindability is the Bond work index (Wi). This measures the resistance of materials to breakage. The Bond standard grindability test has been described in detail by Deister (1987) and Levin (1989) who proposed method to determine the grindability of fine materials (Wills, 2006).

Abdullahi (1997) examined the work index of Ashaka limestone in Gombe state using the modified Bond's method. Here, a reference ore of known weight was ground for 10 minutes at a particular speed and the power consumed was determined from the power rating of the ball mill. An identical weight of the limestone whose work index was to be determined was ground in the same ball mill at the same time and speed as the reference ore such that the same amount of power is consumed in grinding the two minerals. Size analysis of the ball mill for the same duration feed and discharged for the two minerals were carried out. The work index was found to be approximately 9.00 KWh/ton.

Ajayi (1998) determined the work index of Julius Berger Granite in Kogi State of Nigeria using the modified Bond's method. The work index was found to be approximately 14.10 KWh/ton. Procedure for caliberating the tests machine and for preparing the standard reference coal samples was followed. The standard is identical with ISO 5074:1994. Imanishi (1985) carried out grindability tests of various types of ore and coal and a new classification of iron ores was proposed on the basis of the ore forming temperature of deposits. The work indices of magnetite and hematite minerals ranged between 12.5 approx 24.1 KWh/ton and 6.5 approx 23.8 KWh/ton, respectively, and, in both cases increased with the ore forming temperature.

Materials and Method

Location of the Study Area

Itakpe hill is located about 500 km North East of Lagos, 10 km North East of Okene, and about 50 km South of Lokoja, the Kogi State capital. Itakpe hill , an important source of iron ore, is named after an Ebira traditional priest called "ITAKPE" Mining in place in Itakpe since the existence of our forefathers. The Julius Berger Granite quarry is located 330^0 NW of Ajaokuta and 222^0 SW of Geregu on the west bank of River Niger, and approximately 63 kilometers away from Ajaokuta village and 49.5 kilometers from Geregu (Fig. 1)

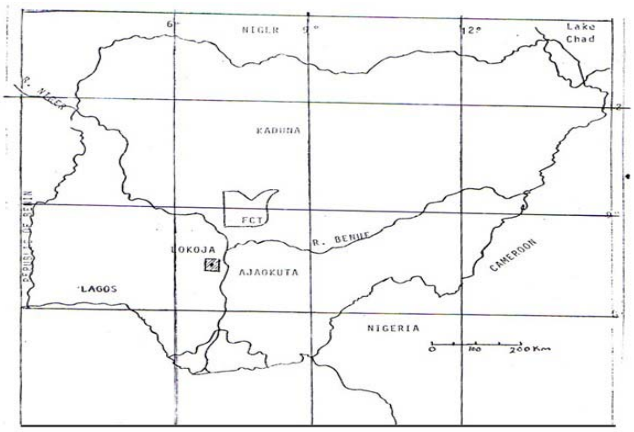

Fig. 1 Location Map of the Study Area

Methods

Determination of Specific Gravity

The specific gravity of the rocks was determined severally using iron ore sample and the average was used.

Specific gravity is defined as the ratio of mass of rock specimen to that of an equal volume of water at a specific temperature.

An empty measuring cylinder was weighed on the electronic weighing balance and the weight was recorded as w_1. The measuring cylinder was filled with water up to the 50 ml (50 cm^3) mark, weighed and then recorded as w_2. The iron ore sample was put into the measuring cylinder which was filled with water to about 50 ml and weighed again and recorded as w_3. This same method was applied to granite rock sample. The specific gravity, (S. G) of the specimen was derived by using the following expression.

$$S.G = \frac{W_3 - W_2}{W_2 - W_1} \quad (1)$$

Where:

W_1 = Weight of empty measuring cylinder

W_2 = Weight of empty cylinder + water

W_3 = Weight of empty cylinder + rock sample + water

$$SG_i = \frac{W_3 - W_2}{W_2 - W_1}$$

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$$SG = \frac{\sum_{i=A}^{D} SG_i}{4}$$

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$$SG_i = \frac{W_3 - W_2}{W_2 - W_1}$$

$$SG = \frac{1.063 + 0.708 + 0.667 + 0.708}{4} = 0.786$$

TABLE 1 SPECIFIC GRAVITY OF GRANITE ROCK

	A	B	C	D
W1	1.080	1.080	1.080	1.080
W_2	1.570	1.560	1.560	1.560
W_3	1.900	1.870	1.870	1.880
SG_i	0.673	0.646	0.646	0.667

TABLE 2 SPECIFIC GRAVITY OF IRON-ORE

	A	*B*	*C*	*D*
W1	1.080	1.080	1.080	1.080
W2	1.560	1.560	1.560	1.560
W3	2.070	1.900	1.880	1.900
SGi	1.063	0.708	0.667	0.708

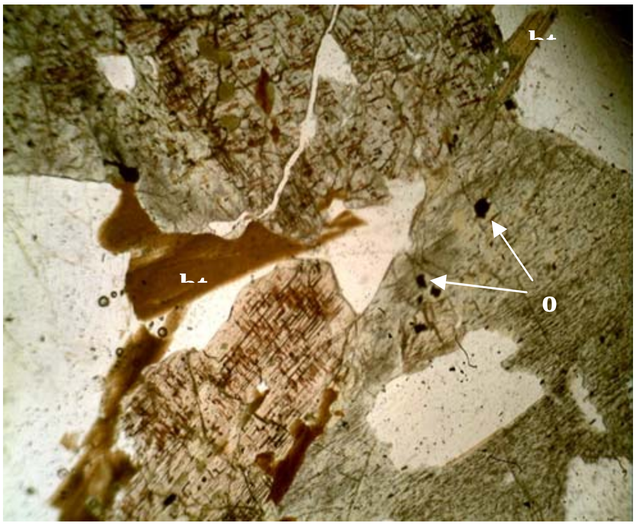
Determination of Mineralogical Composition of Granite

A piece of granite sample was cut to the size of 8 x 20 x 30 mm using Diamond saw cutting machine and the sides were trimmed. The cut piece (specimen) was mounted on a glass slide and its surface ground to flatten it about 90μ m using a grinding machine. The grounded surface was lapped (smotten) to 30 μm using carborundun grits and water in a glass plate. Finally, a cover slip was used to cover the lapped section on a glass slide. The slide was then observed under a microscope and then modal analysis was carried out to know the minerals present in the rock, their percentages and as well as names of the rocks based on the result obtained as shown in table 3.

TABLE 3 MODAL ANALYSIS OF JULIUS BERGER GRANITE QUARRY ROCK.

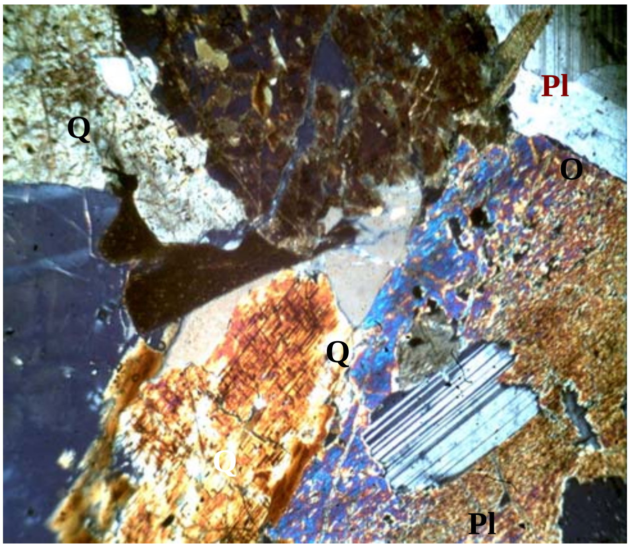
Mineral	**1st count**	**2nd count**	**3rd count**	**4th count**	**5th count**	**Total**	**percentage**
Quartz	7	7	7	7	8	36	31.03
Microcline	3	4	4	4	3	18	15.52
Orthoclase	3	3	3	3	3	15	12.93
Plagioclase	3	4	3	3	3	16	13.79
Biotite	4	6	7	5	7	29	25.00
Accessory Minerals							
Hornblende	-	-	1	-	-	1	
Opaque	-	-	1	-	-	1	1.72
Sphene	-	-	-	-	-		
Grand Total						116	99.99

Accessory Minerals: Hornblende, Opaque and Sphene.
Rock Name: Granite (Porphyritic)
Major Minerals: Quartz, Microcline, Orthoclase, Plagioclase and Biotite.



bt – Biotite, opq – Opaque mineral (Magnification: x4)

FIG. 2 PHOTOMICROGRAPH OF JULIUS BERGER GRANITE ROCK AJAOKUTA UNDER PLAIN POLARIZED LIGHT (PPL).



Qtz – Quartz, Plg – Plagioclase Feldspar,

Ort – Orthoclase Feldspar. (Magnification: x4)

FIG. 3 PHOTOMICROGRAPH OF JULIUS BERGER GRANITE ROCK AJAOKUTA UNDER CROSSED NICHOLS (CN)

Determination of Mineral Composition of Iron Ore

The lump ore samples were crushed mechanically and sieved to give particles in the size range 1-1.7 mm (16-10 mesh). Care was taken to ensure that this size fraction was representative of the lump material. Analysis on calcium, magnesium, iron, aluminium and manganese was made by atomic absorption spectrometry; and silica was determined by a combination of gravimetric and colorimetric methods. X-ray diffraction analysis was performed using Cu-Ka radiation in a Siemens Kristalloflex 4 diffractometer. Samples were ground to 50-70 µm before mounting in thin layers on glass slides with collodion. For optical microscopy, the samples were mounted in an acrylic medium and prepared in the conventional manner. A Cambridge 180 scanning electron microscope with a Kevex energy-dispersive detector was used for morphological studies and phase identification.

X-ray Diffraction Analysis

Three distinct phases were identified in the Itakpe ore by optical microscopy, these appearing as grey, white and mottled white/black areas in the micrograph in Fig. 4. Examination by scanning electron microscopy/energy-dispersive analysis showed that the grey phase was quartz, the white phase hematite, and the mottled areas intergrowths of hematite and magnetite.

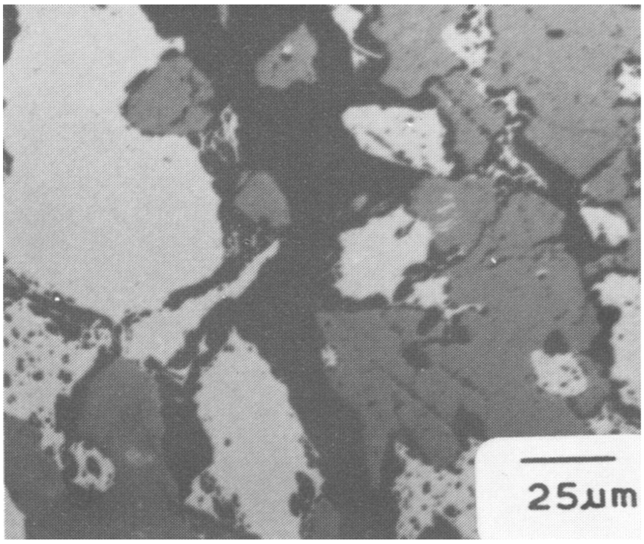


FIG. 4 OPTICAL PHOTOMICROGRAPH OF ITAKPE ORE.

Sieve Analysis of Granite Rock and Iron Ore

A set of sieves numbering up to seven was selected to carry out the sieve analysis of the samples. The material after crushing and milling was sent for test sieving. Test sieves of 4750, 2000, 1700, 850, 600, 425 and 212, 150 microns were used. 2000 grams of pulverized sample were used. The sample to be sieved was placed in the uppermost coarsest sieve which is 4750, and the 2000,1700, 1180, 850 600, 425, 212, and 150 microns were arranged according to the degree of fineness and a bottom pan was placed to collect the undersize, (Fig. 5b). The topmost sieve was covered with a lid. The vibrating sieve shaker has a timer which was set for 10minutes, (Fig. 5a).

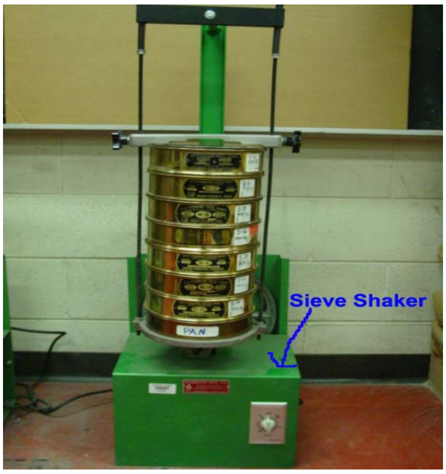


FIG. 5A SIEVES SHAKER

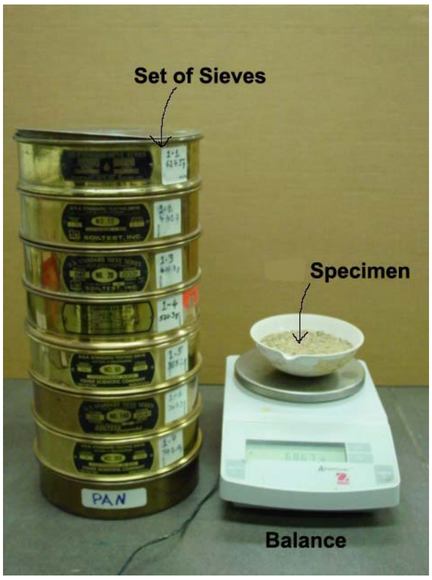


FIG. 5B SET OF SIEVES

After the arrangement of the sieves, the nest was then placed on the automatic sieve shaker, which vibrated the material in a vertical plane and on zone models of horizontal plane. During the shaking duration, the undersized materials fell through successive sieves until they are retained on a sieve having apertures slightly smaller than the diameter of the particles. In this way, the sample was separated into size fractions. After the present time has elapsed, the nest was taken apart and the amount of materials retained on each sieve was weighed. Most of the near mesh particles, which blocked the openings, were removed by inverting the sieve and tapping the frame gently, failing this, the undersized gauze may be brushed gently with a soft brass wire brush.

Determination of Moisture Content

These were carried out by weighing the specimen at natural water content by using electronic balance. The specimens were dried in the oven (Gallen Kamp muffle furnace), at a standard temperature of 105^{0}C for twenty four hours. The specimens were left inside the desiccators to cool and reweighed to determine their dry weight and moisture content i.e. water loss. Granite

$$Moisture\ Content = \frac{Weight\ of\ Wet\ Sample - Weight\ of\ Dry\ Sample}{Weight\ of\ Dry\ Sample} \times 100\%$$

$$= \frac{300 - 298}{298} \times 100\%$$

$$= 0.67\% \tag{2}$$

Determination of Grindability of Iron Ore/Granite Rock

Ore grindability refers to the ease with which materials can be comminuted and data from grindability test are used to evaluate crushing and grinding efficiency. The sieve analysis was carried out, and weight retained on the 4750 μm sieve size was used to carry out the grindability test. Assuming the weight retained on the 4750 μm sieve size is X g. 500 g of the sample was taken and fed into the ball mill. Steel balls weighing 1939 g (1.939 kg) were used in charging the mill and the sample was ground for 10 minutes at an initial speed of N_1 rpm. After this the ground sample was recovered from the ball mill and weighed

The sample was then sieved using the sieve shaker and the material retained on the 150 μm sieve size was weighed and recorded as W_1. This was used in calculating the grindability at N_1rpm which is given as:

$$Grindability, G = \frac{Mass\ at\ 150\mu m\ (Kg)}{Speed\ (rpm)} = {W_1}/{N_1}\ (Kg/rev) \tag{3}$$

An equivalent weight of sample retained on the 150 μm sieve size was taken from X g that was left over and used to top up what was left of the 500 g initially weighted out. This is represented as Y g and again fed into the ball mill. The entire process was repeated for N_2 rpm and subsequently N_3r pm. After each round, the average grindability value was obtained and this was carried out for both iron ore and granite rock

samples obtained from the first sieve analysis. The results are presented in Table 4.

Results and Discussion

TABLE 4 RESULT OF GRANITE SIEVE ANALYSIS

Sieve size range (μm)	Wt Retained (g)	% Wt Retained	Nominal Aperture size(μm)	Cumm % Wt Passing	Cumm % Wt Retained	Log of Sieve Size	Log of Cumm. % Wt Passing
+4750	150.3	30.19	4750	99.99	30.19	3.68	2.0
-4750 +2000	183.1	36.78	4750	68.80	66.97	3.30	1.84
-2000 +1700	10.2	2.05	2000	33.02	69.02	3.23	1.52
-1700 +850	49.7	9.98	1700	30.97	79.00	2.93	1.49
-850 +600	14.81	2.98	850	20.99	81.98	2.78	1.32
-600 +425	15.48	3.11	600	18.01	85.09	2.63	1.26
-425 +212	24.6	4.94	425	14.9	90.03	2.33	1.17
-212 +150	12.89	2.59	212	9.96	92.62	2.18	1.0
-150	36.71	7.37	150	7.37	99.99	-	0.87
Total	497.79	100.00	-	-	-	-	-

TABLE 5 RESULT OF IRON-ORE SIEVE ANALYSIS

Sieve size range (μm)	Wt Retained (g)	% Wt Retained	Nominal Aperture size(μm	Cumm % Wt Passing	Cumm % Wt Retained	Log of Sieve Size	Log of Cumm. % Wt Passing
+4750	60.8	12.19	4750	100.00	12.19	3.68	2.0
-4750 +2000	53.63	10.75	4750	87.81	22.94	3.30	1.94
-2000 +1700	71.16	14.27	2000	77.06	37.21	3.23	1.89
-1700 +850	74.42	14.92	1700	62.97	52.13	2.93	1.80
-850 +600	87.78	17.60	850	47.87	69.73	2.78	1.68
-600 +425	79.12	15.87	600	30.27	85.60	2.63	1.48
-425 +212	46.85	9.40	425	14.40	95.00	2.33	1.16
-212 +150	15.25	3.06	212	5.00	98.06	2.18	0.7
-150	9.65	1.94	150	1.94	100.00	-	0.29
Total	498.66	100.00	-	-	-	-	-

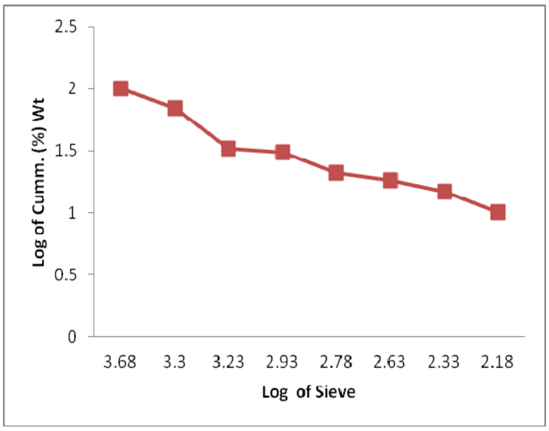


FIG. 6 PLOT OF RESULT OF LOG OF CUMULATIVE % PASSING AGAINST LOG OF SIEVE SIZE FOR GRANITE ROCK

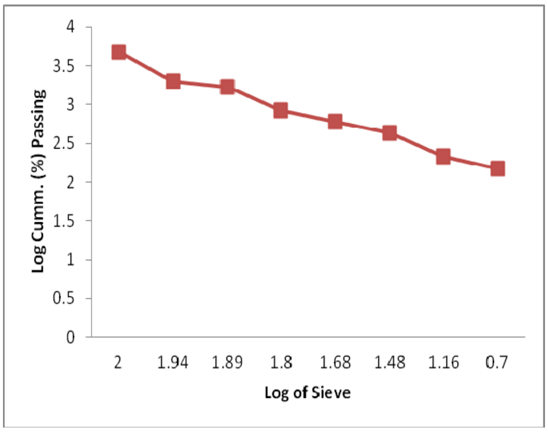


FIG. 7 PLOT OF RESULT OF LOG OF CUMULATIVE % PASSING AGAINST LOG OF SIEVE SIZE FOR IRO

TABLE 6 GRINDABILITY OF GRANITE ROCK

No of Rev (N)	1st Run		2nd Run		Average G_{av}
	$W_{-x}(g)$	$A=\frac{W_{-x}}{N}$	$W_{-x}(g)$	$B=\frac{W_{-x}}{N}$	$\frac{(A+B))}{2}$
100	3.4	0.03	10.3	0.10	0.069
150	4.1	0.03	14.1	0.09	0.061
200	7.7	0.04	9.7	0.05	0.044
250	18.5	0.07	16.8	0.07	0.071
300	18.3	0.06	19.4	0.06	0.063

$$G_r = \frac{\sum\left(\frac{(A+B)}{2}\right)}{5}$$

TABLE 7 GRINDABILITY OF IRON-ORE

No of Rev	1st Run		2nd Run		Average G_{av}
	$W_{-x}(g)$	$A=\frac{W_{-x}}{N}$	$W_{-x}(g)$	$B=\frac{W_{-x}}{N}$	$\frac{(A+B))}{2}$
100	88.4	0.884	99.2	0.992	0.938
150	143.8	0.959	137.5	0.917	0.938
200	183.7	0.919	187.6	0.938	0.928
250	222.4	0.890	231.5	0.926	0.908
300	263.9	0.880	288.4	0.961	0.921

From the calculations above, the grindability index for Granite rock is 0.061, while that of Iron-Ore is 0.926. This implies that Granite is harder than Iron-Ore, as confirmed by Wills (2006) who stated that Ore grindability refers to the ease with which materials can be comminuted.

Conclusion

Silica was seen in iron-ore as the major impurity, which appears in form of coarse grains, hence the appearance and nature of this mineral (Silica) affected its grindability. Similarly, the fragmented granite rock was also affected due to the coarse grains of quartz mineral in the rock. Assuming these minerals appears in fine grains then its grindability would not be affected, and this is in line with Linda (2008) argument. Based on this fact, it is recommended that the grindability test should be conducted before a processing plant is set up.

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